IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Kari PAJUKOSKI et al.	Group Art Unit: Unassigned
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For: COMMUNICATION METHOD, RECEIVER AND BASE STATION

CLAIM FOR PRIORITY UNDER 35 USC § 119

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450   January 21, 2004

Sir:

The benefit of the filing date of the following prior foreign application filed in the following foreign country is hereby requested for the above-identified patent application and the priority provided in 35 U.S.C. §119 is hereby claimed:

Patent Application No. 20031609 filed on November 16, 2003 **in** Finland

In support of this claim, certified copy of said original foreign application is filed herewith.

It is requested that the file of this application be marked to indicate that the requirements of 35 U.S.C. §119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of this document.

Please charge any fee deficiency or credit any overpayment with respect to this paper to Counsel's Deposit Account No. 50-2222.

Respectfully submitted,

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Enclosure: Priority Document (1)

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PRIORITY DOCUMENT

Hakija Applicant	**Nokia Corporation** **Helsinki**
Patenttihakemus nro Patent application no	20031609
Tekemispäivä Filing date	06.11.2003
Kansainvälinen luokka International class	**H04B**
Keksinnön nimitys Title of invention	

"Communication method, receiver and base station"
(Viestintämenetelmä, vastaanotin ja tukiasema)

Täten todistetaan, että oheiset asiakirjat ovat tarkkoja jäljennöksiä
Patentti- ja rekisterihallitukselle alkuaan annetuista selityksestä,
patenttivaatimuksista, tiivistelmästä ja piirustuksista.

This is to certify that the annexed documents are true copies of the
description, claims, abstract and drawings originally filed with the
Finnish Patent Office.

Pirjo Kaila
Tutkimussihteeri

Maksu   50 €
Fee   50 EUR

*Maksu perustuu kauppa- ja teollisuusministeriön antamaan asetukseen 1027/2001
Patentti- ja rekisterihallituksen maksullisista suoritteista muutoksineen.*

*The fee is based on the Decree with amendments of the Ministry of Trade and Industry No.
1027/2001 concerning the chargeable services of the National Board of Patents and
Registration of Finland.*

Communication Method, R ceiv r and Base Station

Field

The invention relates to a method for reducing the influence of inter-ference in a multi-user receiver, when the multi-user receiver receives signals from users having different data rates using at least two antenna elements. The invention also relates to a multi-user receiver and a base station.

Background

Several combining techniques have usually been used to combine diversity antennas or different antenna branches in antenna arrays to create nulls towards interfering signals while maintaining a large antenna gain to-wards the desired signal, thus reducing interference. One example of combin-ing techniques is interference rejection combining (IRC). Conventionally the IRC is carried out at symbol level after despreading operations. This requires that the IRC operations need to be implemented separately for each user, thus increasing the complexity of a receiver. For simplifying the receiver structure, the IRC technique is combined with a maximal ratio combining (MRC) tech-nique, whereupon an IRC filter acts as a pre-whitening filter in WO 02/075950. The IRC technique is also examined in Esa Tiirola, Juha Ylitalo: Performance of Smart Antenna Receivers in WCDMA Uplink with Spatially Coloured Inter-ference, IST Mobile Communications Summit 2001, Barcelona, Spain, 9. - 12.9.2001, which is incorporated herein by reference. While the IRC technique is used in a pre-whitening filter, the pre-whitening is carried out by antenna weighting, which is performed on all users. Thus there arises a problem: the high bit rate users are seen as relatively high level interferers to low bit rate users and therefore taken into account when determining whitening weights. As a consequence of this, in whitening, the combining of antenna signals is not optimal from the high data rate user's point of view. The use of a non-optimal solution will diminish the uplink coverage of high data rate users and at the same time increase the user terminal's battery consumption for the high bit rate users.

Brief description of the invention

The invention provides an improved method, receiver and base sta-tion.

According to an embodiment, there is provided a method for reducing the influence of interference in a multi-user receiver, when the multi-user receiver receives signals from users having different data rates using at least two antenna elements, the method comprises: creating a spatial covariance

5 matrix estimate from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, determining a whitening filter on the basis of the spatial covariance matrix estimate, whitening received signals by using the whitening filter, removing the whitening from signals of predetermined users by using

10 an inverse matrix of the matrix used in the whitening filter, conveying whitened signals and the signals from which the whitening has been removed to a receiver element, which carries out multi-path combining and multi-antenna combining.

According to another embodiment, there is provided a multi-user re-
15 ceiver which uses at least two antenna elements and in which the influence of interference is reduced, the receiver comprises: means for pre-filtering a wideband antenna signal, the pre-filtering means being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled

20 values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, means for removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter, means for performing multi-path combining and multi-antenna combining.

According to another embodiment, there is provided a multi-user re-
25 ceiver which uses at least two antenna elements and in which the influence of interference is reduced, the receiver comprises: one branch with a whitening arrangement, another branch without a whitening arrangement and a switching arrangement conveying received signals to the branch with the whitening arrangement or to the branch without the whitening arrangement depending on

30 the used bit rate, a receiver element performing multi-path combining and multi-antenna combining.

According to another embodiment, there is provided a multi-user receiver in which the influence of interference is reduced, comprising: a pre-filter whitening a wideband antenna signal, the pre-filter being determined on the

35 basis of a spatial covariance matrix estimate which spatial covarianc matrix estimate is obtained from wideband antenna signals by sampling, arranging

sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, a whitening removing arrangement removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter, a receiver element performing multi-path 5 combining and multi-antenna combining.

According to another embodiment, there is provided a base station comprising a multi-user receiver which receiver uses at least two antenna elements and in which base station the influence of the interference is reduced, the base station comprises: means for pre-filtering a wideband antenna signal, 10 the pre-filtering means being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, means for removing the whitening from signals of predetermined users by us- 15 ing an inverse matrix of the matrix used in the whitening filter, means for performing multi-path combining and multi-antenna combining.

According to another embodiment, there is provided a base station comprising a multi-user receiver which uses at least two antenna elements and in which base station the influence of the interference is reduced, the base sta- 20 tion comprises: one branch with a whitening arrangement, another branch without a whitening arrangement and a switching arrangement conveying received signals to the branch with the whitening arrangement or to the branch without the whitening arrangement depending on the used bit rate, an element performing multi-path combining and multi-antenna combining.

25 According to another embodiment, there is provided a base station comprising a multi-user receiver which uses at least two antenna elements and in which base station the influence of the interference is reduced, the receiver comprises: a pre-filter whitening a wideband antenna signal, the pre-filter being determined on the basis of a spatial covariance matrix estimate, which spatial 30 covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, a whitening removing arrangement removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter, an element per- 35 forming multi-path combining and multi-antenna combining.

The method and system of the invention provide several advantages. In one embodiment of the invention, the whitening performed by a pre-whitening filter can be removed from predetermined users and therefore the signals can be combined optimally. In another embodiment of the invention, the predetermined users are conveyed to by-pass a pre-whitening filter, thus preventing disadvantages caused by whitening.

List of drawings

In the following, embodiments of the invention will be described in greater detail with reference to the preferred embodiments and the accompanying drawings, in which

Figure 1 shows an example of a method for reducing the influence of interference in a multi-user receiver,

Figure 2 illustrates an example of a receiver structure for reducing the influence of interference in a multi-user receiver,

Figure 3 shows an example of a receiver structure for reducing the influence of interference in a multi-user receiver.

Description of embodiments

With reference to Figure 1, let us examine an embodiment of a method for reducing the influence of interference in a multi-user receiver. The method may be used in several kinds of radio receivers, such as a base station of a communication system, for instance a base station used in a wideband code division multiple access system (WCDMA), such as UMTS (universal mobile telecommunications system). The receiver may, for example, be a Rake receiver or a receiver having diversity antennas. The embodiment is directed to a receiver having a pre-whitening filter in the front-end of an MRC receiver.

The embodiment is especially suitable for systems where there are users having different bit rates, for example, the majority of users use low bit rate services and some users use high bit rate services and the receiver uses several antenna elements. Data rates, which are classified as low or high, vary according to the current system; the data rates tend to increase due to technology d v lopment. In this application, the concept of high bit rate users means users having a relatively high bit rate and low bit rate users mean users having a relativ ly low bit rate. It is possible to set a bit rate threshold and classify users exceeding it as high bit rate users.

The embodiment starts in block 100. In block 102, a covariance matrix estimate is created from wid band antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector. The signals received by different antennas are preferably sampled simultaneously, for which reason sampled values are arranged into a vector format. The size of the vector depends on the number of antennas. Several sampling methods are known in the art and therefore they are not explained here in further detail.

The wideband antenna signal vector representing the desired signal of a single user, related interference and noise can be defined as

$$x_i(j) = \sum_l \mathbf{h}_l y_i(j - \tau_l) + \mathbf{u}_i(j) \tag{1}$$

wherein

$\mathbf{h}$ is a channel model as a tapped delay line with an impulse response $\sum_l \mathbf{h}_l \delta(j - \tau_l)$

$\mathbf{u}_i$ is a vector including interference and noise components of signal samples,

y_i is a complex-valued transmitted signal,

i is a time slot index,

j is a chip index,

δ means the Dirac's delta function,

τ means a relative delay of a multi-path component,

$\sum$ means summing.

The signal spatial covariance matrix is then calculated by multiplying the signal vector (1) by its conjugate transpose (Hermitian) vector $x_i(j)^H$.

The spatial covariance estimate matrix is typically averaged over a selected period of time, for instance, the averaging length can be chosen to be a time slot or a fraction of it.

The spatial covariance estimate matrix averaged over a time slot having 2560 chips can be expressed as follows

$$\hat{\mathbf{R}}_{xx,i} = \frac{1}{2560} \sum_{j=1}^{2560} x_i(j) x_i(j)^H \tag{2}$$

wherein

x_i is a wideband antenna signal matrix,

i is a time slot index,

j is a chip index.

Σ means summing.

In block 104, a whitening filter is determined on the basis of the co-variance matrix estimate. The whitening filter is typically implemented by using a whitening filter matrix. The whitening filter matrix may be obtained in such a way that is satisfies

$$\mathbf{W}_i \mathbf{W}_i^H = \hat{\mathbf{R}}_{xx,i}^{-1} \qquad (3)$$

wherein

$\hat{\mathbf{R}}_{xx,i}$ is a covariance matrix estimate,

$\mathbf{W}_i$ is a whitening filter matrix,

$\mathbf{W}_i^H$ is a complex-conjugate (Hermitian) matrix of the whitening filter matrix,

$^{-1}$ denotes inversion.

The whitening filter matrix can be solved by using Cholesky decom-position, because matrix $\hat{\mathbf{R}}_{xx,i}$ is a symmetric and positive definite matrix. The Cholesky decomposition of the spatial covariance matrix estimate $\hat{\mathbf{R}}_{xx,i}$ may be written as

$$\hat{\mathbf{R}}_{xx,i} = \mathbf{U}^H \mathbf{U} \qquad (4)$$

wherein

$\mathbf{U}$ is an upper triangular matrix.

If the filter $\mathbf{W}$ is chosen as the inverse of the Cholesky factor, i.e.,

$$\mathbf{U}\mathbf{W} = \mathbf{I}_m \qquad (5)$$

wherein

$\mathbf{I}_m$ is an identity matrix of size m, then it follows that the equation (3) is satisfied.

In block 106, received signals are whitened by using the whitening filter. The whitening may be carried out by a complex matrix multiplication.

The purpose of whitening is to whiten coloured noise or interfer-ence, which means that the powers of interfering signals are transformed by filtering to be similar to that of white Gaussian noise. The whitening adjusts signals for the MRC (maximal ratio combining) because the MRC performance

is optimal in case that noise or interference is spatially white Gaussian. The assumption of spatially white Gaussian noise is valid for the interference scenario with a large number of low bit rate users. When there are also high bit rate users, the interference is coloured, in other words the interference is not uncorrelated between different antennas. Whitened received signals (received chips) obtained by matrix multiplication may be written as

$$\mathbf{x}_{w,i}(j) = \mathbf{W}_i \mathbf{x}_i(j) \tag{6}$$

wherein
$\mathbf{W}_i$ is a whitening filter matrix,
$\mathbf{x}_i$ is a wideband antenna signal matrix,
i is a time slot index,
j is a chip index.

In block 108, the whitening is removed from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter. Removing is typically carried out by matrix multiplication. The removing may be carried out in different places in a reception chain: if the whitening is removed from channel estimates, the channel impulse response matrix is multiplied by the inverse matrix of the whitening matrix, or if the whitening is removed from despread data, the despread data arranged in a matrix format is multiplied by the inverse matrix of the whitening matrix, for example. The whitening is removed from predetermined signals, which in practice can be implemented, for instance, by using a bit rate threshold: the whitening is removed from signals exceeding the threshold.

In practice, the whitening is preferably carried out before a prior art MRC (maximal ratio combining) receiver. The removing of the whitening may also be carried out before the MRC receiver or it may be incorporated in it. The principle of the MRC is that different phase offsets of each received signal are estimated and compensated for after demodulation, the power level of each received signal is estimated and the phase-corrected demodulator outputs are weighted in direct proportion of the received signal strength, the phase-corrected and weighted signals are summed and fed to the detector. The MRC technique is known in the art and is therefore not explained here in greater detail.

In block 110, whitened signals and the signals from which the whitning has been removed are conveyed to a receiver element, which carries out

multi-path combining and multi-antenna combining. The element performing multi-path combining and multi-antenna combining may be a maximum ratio combiner. In one embodiment, the multi-path combining and the multi-antenna combining are carried out according to the Rake principle. Arrow 116 depicts

5   that both whitened signals and signals from which the whitening has been removed are conveyed to the multi-path combining and multi-antenna combining.

The embodiment ends in block 112. Arrow 114 depicts one possibility for repeating the embodiment. A generalised example of a part of a receiver depicted by Figure 2 is now examined. It is obvious to a person skilled in the

10   art that the receiver may also include elements other than those illustrated in Figure 2. The receiver may be located in several kinds of communication units, such as a base station of a communication system, for instance a base station used in a wideband code division multiple access system (WCDMA), such as UMTS (universal mobile telecommunications system). The receiver may, for

15   example, be a Rake receiver.

The receiver includes an antenna array or diversity antennas 212, 214. The number of antennas may vary according to the implementation. The IRC block 200 is a pre-whitening filter carrying out whitening operation. The pre-whitening filter is determined on the basis of a spatial covariance matrix

20   estimate, which is obtained from the sampled antenna signals. The pre-whitening filter determination is explained above with the aid of the embodiment depicted in Figure 1.

The MRC receiver structure 216 includes in this embodiment one receiver element 202, 204, 206, 208, 210 per each user. Some of them 202,

25   204, 206, 208 are for low bit rate users and one 210 for a high bit rate user. The number of MRC receiver elements may vary according to the implementation. In this embodiment, the MRC receiver elements use the Rake principle for multi-path combining and multi-antenna combining.

Low bit rate users are conveyed to their MRC receiver elements for

30   MRC processing. The MRC process includes estimation and compensation for phase offsets of each received signal after demodulation, power level estimation of each received signal, weighting of phase-corrected demodulator outputs in direct proportion of the received signal strength and summation of the phase-corrected and weighted signals. The output of each MRC receiver ele-

35   ment is then conveyed to th detector 220. The MRC technique is known in the art and is therefore not explained here in greater detail.

The predetermined user, typically a high bit rate user, is conveyed to its MRC element, where the whitening carried out by a pre-whitening filter 200 is removed by using an inverse matrix W_r^{-1} of the matrix used in the whitening filter. Removing is typically carried out by matrix multiplication. The re-

5 moving may be carried out in different points of a transmission chain: if the whitening is removed from channel estimates, the estimate channel impulse response matrix is multiplied by the inverse matrix of the whitening matrix, or if the whitening is removed from despread data, the despread data arranged in a matrix format is multiplied by the inverse matrix of the whitening matrix, for ex-

10 ample. The whitening is removed from predetermined signals, which in practice can be implemented, for instance, by using a bit rate threshold: the whitening is removed from signals exceeding the threshold. The removing may also be carried out in a separate removing block in the front end of a MRC receiver or receiver element.

15 The control block 218 controls the function of the MRC receiver and also the removing of whitening. The whitening and the removing of whitening are typically implemented according to the present embodiment as a processor and software, but different hardware implementations are also feasible, e.g. a circuit built of separate logic components or one or more client-specific inte-

20 grated circuits (Application-Specific Integrated Circuit, ASIC). A hybrid of these implementations is also feasible.

Next another generalised example of a part of a receiver is examined with the aid of Figure 3. The receiver of this embodiment includes one branch with a whitening procedure and another branch without a whitening

25 procedure. Received signals are conveyed to the branch with the whitening procedure or to the branch without the whitening procedure depending on the used bit rate.

It is obvious to a person skilled in the art that the receiver may also include elements other than illustrated in Figure 3. The receiver may be lo-

30 cated in several kinds of communication units, such as a base station of a communication system, for instance a base station used in a wideband code division multiple access system (WCDMA), such as UMTS (universal mobile telecommunications system). The receiver may, for example, be a Rake receiver.

35 The receiver includes an antenna array or diversity antennas 312, 314. The number of antennas may vary according to the implem ntation. The

IRC block 300 is a pre-whitening filter carrying out whitening operation. The pre-whitening filter is determined on the basis of a spatial covariance matrix estimate, which is obtained from the sampled antenna signals. The pre-whitening filter determination is explained above with the aid of the embodi-
5   ment depicted in Figure 1.

The receiver also includes logical MRC receivers 302, 304, 306, 308 for low bit rate users and one 310 for a high bit rate user. There are available two connections per antenna: one 322A, 324A for wideband antenna signal passing the pre-whitening filter (IRC block) 300 and another one 322B, 324B
10   which conveys signals to the pre-whitening filter. There is also a switching block 318 which switches low bit rate users to their MRC receivers 302, 304, 306, 308 and a high bit rate user to its MRC receiver 310. In this embodiment, the MRC receiver elements use the Rake principle for multi-path combining and multi-antenna combining. The MRC process includes estimation and com-
15   pensation for phase offsets of each received signal after demodulation, power level estimation of each received signal, weighting of phase-corrected de-modulator outputs in direct proportion of the received signal strength and summation of the phase-corrected and weighted signals. The output of each MRC receiver element is then conveyed to the detector 320. The MRC tech-
20   nique is known in the art and is therefore not explained here in greater detail.

The control block 316 controls the function of the switching block 318 according to the user's bit rate conveying the high bit rate users to by-pass the pre-whitening filter 300. The switching is typically implemented as a hardware implementation.
25   Even though the invention is described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but it can be modified in several ways within the scope of the appended claims.

Claim

1. A method for reducing the influence of interference in a multi-user receiver, when the multi-user receiver receives signals from users having different data rates using at least two antenna elements, c h a r a c t e r i z e d in

5   that the method comprises:

(102) creating a spatial covariance matrix estimate from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector,

(104) determining a whitening filter on the basis of the spatial co-

10   variance matrix estimate,

(106) whitening received signals by using the whitening filter,

(108) removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter,

(110) conveying whitened signals and the signals from which the

15   whitening has been removed to a receiver element, which carries out multi-path combining and multi-antenna combining.

2. The method of claim 1, c h a r a c t e r i z e d in that the whitening is carried out by matrix vector multiplication.

3. The method of claim 1, c h a r a c t e r i z e d in that the receiver

20   uses maximum ratio combining for performing multi-path and multi-antenna combining according to the Rake principle.

4. The method of claim 1, c h a r a c t e r i z e d in that the whitening filter is determined by using Cholesky decomposition.

5. The method of claim 1, c h a r a c t e r i z e d in that the users

25   from whom the whitening is removed are determined on the basis of a bit rate threshold.

6. A multi-user receiver which uses at least two antenna elements and in which the influence of interference is reduced, c h a r a c t e r i z e d in that the receiver comprises:

30   means (200) for pre-filtering a wideband antenna signal, the pre-filtering means being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector,

means (210, 218) for removing the whitening from signals of prede-
t rmined users by using an inverse matrix of the matrix used in the whitening
filter,

means (202, 204, 206, 208, 210) for performing multi-path combin-
5 ing and multi-antenna combining.

7. A multi-user receiver which uses at least two antenna elements
and in which the influence of interference is reduced, c h a r a c t e r i z e d in
that the receiver comprises:

one branch (322B, 324B) with a whitening arrangement (300), an-
10 other branch (322A, 324A) without a whitening arrangement and a switching
arrangement (318) conveying received signals to the branch with the whitening
arrangement or to the branch without the whitening arrangement depending on
the used bit rate,

a receiver element (302, 304, 306, 308, 310) performing multi-path
15 combining and multi-antenna combining.

8. A multi-user receiver in which the influence of interference is re-
duced, comprising:

a pre-filter (200) whitening a wideband antenna signal, the pre-filter
being determined on the basis of a spatial covariance matrix estimate which
20 spatial covariance matrix estimate is obtained from wideband antenna signals
by sampling, arranging sampled values into a signal vector and by multiplying
the signal vector by its conjugate transpose vector,

a whitening removing arrangement (210, 218) removing the whiten-
ing from signals of predetermined users by using an inverse matrix of the ma-
25 trix used in the whitening filter,

a receiver element (202, 204, 206, 208, 210) performing multi-path
combining and multi-antenna combining.

9. The receiver of claim 6, c h a r a c t e r i z e d in that the whitening
is carried out by complex matrix multiplication.

30 10. The receiver of claim 7, c h a r a c t e r i z e d in that the whiten-
ing is carried out in the whitening arrangement (300) by complex matrix multi-
plication.

11. The receiver of claim 7, c h a r a c t e r i z e d in that the receiver
element (202, 204, 206, 208, 210, 302, 304, 306, 308, 310) performing the
35 multi-path combining and the multi-antenna combining is a maximum ratio
combiner.

12. The receiver of claim 8, c h a r a c t e r i z e d in that the receiver element (202, 204, 206, 208, 210, 302, 304, 306, 308, 310) performing the multi-path combining and the multi-antenna combining is a maximum ratio combiner.

13. The receiver of claim 6, c h a r a c t e r i z e d in that the means (202, 204, 206, 208, 210) for performing the multi-path combining and the multi-antenna combining is a maximum ratio combiner.

14. The receiver of claim 6, c h a r a c t e r i z e d in that the receiver further comprises means (218, 316) for determining the users from whom the whitening is removed on the basis of a bit rate threshold.

15. The receiver of claim 7, c h a r a c t e r i z e d in that the receiver further comprises means (218, 316) for determining the users from whom the whitening is removed on the basis of a bit rate threshold.

16. The receiver of claim 8, c h a r a c t e r i z e d in that the receiver further comprises means (218, 316) for determining the users from whom the whitening is removed on the basis of a bit rate threshold.

17. A base station comprising a multi-user receiver which receiver uses at least two antenna elements and in which base station the influence of the interference is reduced, c h a r a c t e r i z e d in that the base station comprises:

means (200) for pre-filtering a wideband antenna signal, the pre-filtering means being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector,

means (210, 218) for removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter,

means (202, 204, 206, 208, 210) for performing multi-path combining and multi-antenna combining.

18. A base station comprising a multi-user receiver which uses at least two antenna elements and in which base station the influence of the interference is reduced, c h a r a c t e r i z e d in that the base station comprises:

one branch (322B, 324B) with a whitening arrangement (300), another branch (322A, 324A) without a whitening arrangement and a switching arrangement (318) conveying received signals to the branch with the whitening

arrangement or to the branch without the whitening arrangement depending on the used bit rate,

an element (302, 304, 306, 308, 310) performing multi-path combining and multi-antenna combining.

19. A base station comprising a multi-user receiver which uses at least two antenna elements and in which base station the influence of the interference is reduced, c h a r a c t e r i z e d in that the receiver comprises:

a pre-filter (200) whitening a wideband antenna signal, the pre-filter being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector,

a whitening removing arrangement (210, 218) removing the whitening from signals of predetermined users by using an inverse matrix of the matrix used in the whitening filter,

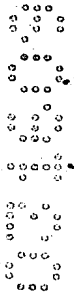an element (202, 204, 206, 208, 210) performing multi-path combining and multi-antenna combining.
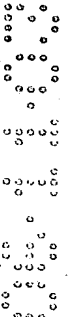
(57) Abstract

A multi-user receiver which uses at least two antenna elements and in which the influence of interference is reduced, the receiver comprises: means (200) for pre-filtering a wideband antenna signal, the pre-filtering means being determined on the basis of a spatial covariance matrix estimate, which spatial covariance matrix estimate is obtained from wideband antenna signals by sampling, arranging sampled values into a signal vector and by multiplying the signal vector by its conjugate transpose vector, means (210, 218) for removing the whitening from signals of predetermined users by using an inverse m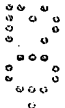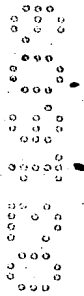atrix of the matrix used in the whitening filter, means (202, 204, 206, 208, 210) for performing multi-path combining and multi-antenna combining.
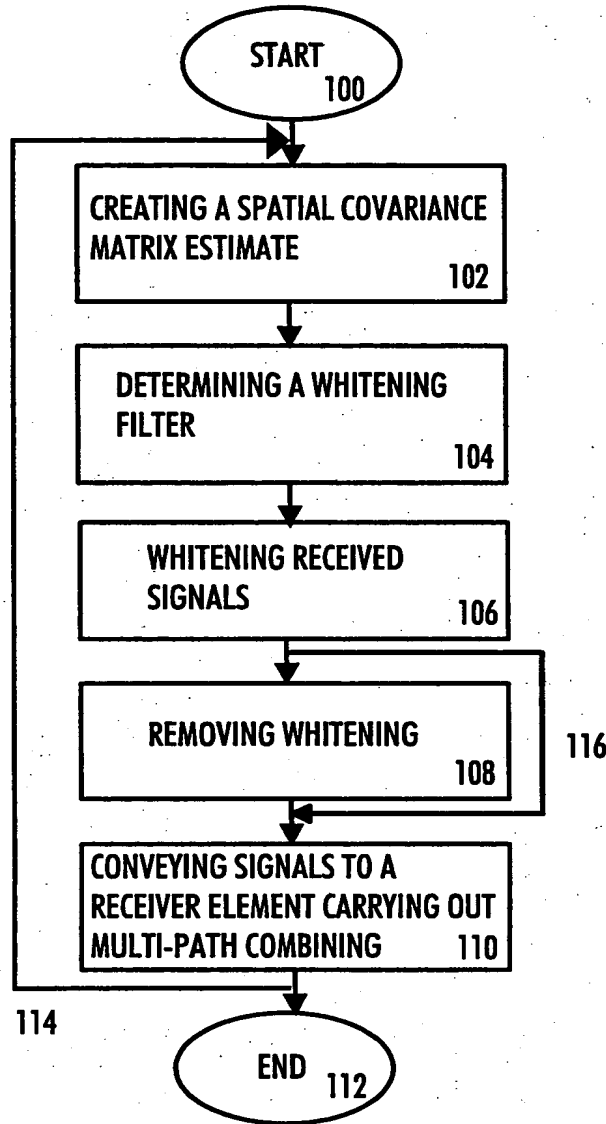
(Figure 2)

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                    ┌─────────────┐
                    │    START    │
                    │         100 │
                    └──────┬──────┘
                           │
    ┌──────────────────────▼──────────────────────┐
    │  ┌────────────────────────────────────────┐  │
    │  │ CREATING A SPATIAL COVARIANCE          │  │
    │  │ MATRIX ESTIMATE                        │  │
    │  │                                   102  │  │
    │  └────────────────────┬───────────────────┘  │
    │                       ▼                       │
    │  ┌────────────────────────────────────────┐  │
    │  │ DETERMINING A WHITENING                │  │
    │  │ FILTER                                 │  │
    │  │                                   104  │  │
    │  └────────────────────┬───────────────────┘  │
    │                       ▼                       │
    │  ┌────────────────────────────────────────┐  │
    │  │ WHITENING RECEIVED                     │  │
    │  │ SIGNALS                                │  │
    │  │                                   106  │  │
    │  └────────────────────┬───────────────────┘  │
    │                       ▼                       │
    │  ┌────────────────────────────────────────┐  │
    │  │ REMOVING WHITENING                     │  │
    │  │                                   108  │──┼── 116
    │  └────────────────────┬───────────────────┘  │
    │                       ▼                       │
    │  ┌────────────────────────────────────────┐  │
    │  │ CONVEYING SIGNALS TO A                 │  │
    │  │ RECEIVER ELEMENT CARRYING OUT          │  │
    │  │ MULTI-PATH COMBINING          110      │  │
    │  └────────────────────┬───────────────────┘  │
    └──────────────────────▲┼──────────────────────┘
     114                    ▼
                    ┌─────────────┐
                    │     END 112 │
                    └─────────────┘
```
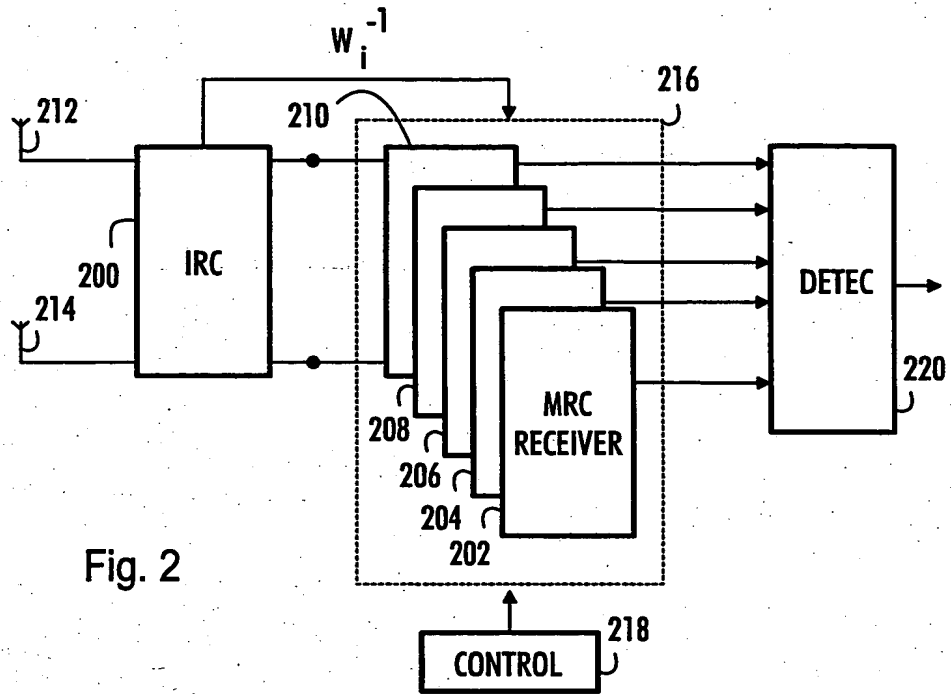
Fig. 1

W_i^{-1}

216

212

210

200   IRC

214

208

206

204

202

MRC
RECEIVER

DETEC

220

Fig. 2

218

CONTROL

SWITCH

312

318

314

310

308

306

304

IRC

300

MRC
RECEIVER

302

DETEC

320

316

CONTROL

Fig. 3